

Remarks.

A. **Amendments.**

Claims 1-15 have been cancelled and claims 21-35 have been added. Thus, claims 16-35 are pending in this Application.

B. **Arguments.**

The rejection of claims 1-15 is now moot because of the cancellation of those claims.

Claims 16-20 stand rejected under 35 U.S.C. § 103 as being unpatentable over Kawakami et al, U.S. Patent No. 5,824,434 ("Kawakami") in view of Zhuang et al. ("Zhuang"). As the Examiner acknowledges, neither Kawakami nor Zhuang teach co-depositing the gaseous material and lithium layer. Applicant submits herewith evidence of the superior results of utilizing the present invention, which includes co-depositing gaseous material and a lithium layer onto a substrate to form an anode.

The three Examples (A-C) below disclose the manufacture of (A) an anode substrate with a deposited lithium layer and no CO₂ treatment, (B) an anode substrate co-deposited with lithium and CO₂, and (C) an anode substrate with a deposited lithium layer post-treated with CO₂ (i.e., rather than co-deposited as claimed herein.) As shown in the Tables following the Examples, the co-deposited lithium/CO₂ anode provided unexpected, ameliorative results. Thus Applicant's method as claimed is not obvious in view of the cited art.

1. Example A: Deposit of Lithium to Form a Lithium Anode with no CO₂ Treatment

A vacuum web coating system located in a dry room, having an unwind drive, a liquid cooled drum at -20 °C, load cell rollers for controlling tension, a rewind drive, and two deposition zones, was loaded with an anode substrate of 23 µm PET metallized on one side with 60 nm of inconel and of 15 cm width. The chamber was evacuated to 10⁻⁶ Torr. Lithium was deposited on to the substrate by first heating a thermal evaporation lithium source to 535 °C to allow significant evaporation, and then starting the web drive at 0.5 feet per minute. The lithium evaporation was allowed to stabilize to give a 10 µm coating of lithium on the inconel of the substrate layer. There was no CO₂ treatment.

2. EXAMPLE B: Co-deposit of Lithium and CO₂

A vacuum web coating system located in a dry room, having an unwind drive, a liquid cooled drum at -20 °C, load cell rollers for controlling tension, a rewind drive, and two deposition zones, was loaded with an anode substrate of 23 µm PET metallized on one side with 60 nm of inconel and of 15 cm width. The chamber was evacuated to 10⁻⁶ Torr. Lithium was deposited on to the substrate by first heating a thermal evaporation lithium source to 535 °C to allow significant evaporation, and then starting the web drive at 0.5 feet per minute. The lithium evaporation was allowed to stabilize to give a 10 µm coating of lithium on the inconel of the substrate layer. Immediately adjacent to the lithium source CO₂ was introduced through a mass flow controller at a flow between 10 and 100 sccm raising the pressure to 0.1 to 50 mTorr. Dark discoloration was immediately seen in the co-deposited lithium with CO₂ from this in situ deposition process.

3. EXAMPLE C: Deposition of Lithium followed by CO₂ Treatment

A vacuum web coating system located in a dry room, having an unwind drive, a liquid cooled drum at -20 °C, load cell rollers for controlling tension, a rewind drive, and two deposition zones, was loaded with an anode substrate of 23 µm PET metallized on one side with 60 nm of inconel and of 15 cm width. The chamber was evacuated to 10⁻⁶ Torr. Lithium was deposited onto the substrate by first heating a thermal evaporation lithium source to 535 °C to allow significant evaporation, and then starting the web drive at 0.5 feet per minute. The lithium

evaporation was allowed to stabilize to give a 10 μm coating of lithium on the inconel of the substrate layer. Upon completion of the deposition the lithium coated substrate was re-wound on the unwind drive while the vacuum was maintained in the apparatus. With the lithium source off, the lithium coated substrate was subjected to RF magnetron plasma treatment with the CO_2 gas. Forward RF power was between 50 and 100 W at a pressure of 0.1 to 50 mTorr. The post treated lithium had a dark appearance.

4. Fabrication of Electrochemical Cells from the Anodes of Examples A, B, and C.

Small flat cells were assembled as follows: A composite cathode was prepared by coating a 3.68 cm wide cathode active layer on a 4.19 cm wide Al/PET substrate. A cathode slurry was prepared from 70 parts by weight of elemental sulfur, 15 parts by weight of conductive carbon, 10 parts by weight of graphite, 4 parts by weight of TA22-8 resin, and 1 part by weight of Ionac PFAZ-322. The solids content of the slurry was 14% by weight in a solvent mixture of 80% isopropanol, 12% water, 5% 1-methoxy-2-propanol and 3% dimethylethanolamine (on a weight basis). The slurry was coated by a slot die coater onto both sides of the substrate. The coating was dried in the ovens of the slot die coater. The resulting dry cathode active layer had a thickness of about 15 microns on each side of the current collector, with a loading of electroactive cathode material of about 0.89 mg/cm^2 . 4.5 cm lengths of this composite cathode were used in building the electrochemical cells.

Lithium anodes of 10 cm in length and 4.19 cm in width were cut from the anode materials of Examples A, B, and C, respectively. Small flat cells were assembled by folding the anode around a cathode with a 10 μm polyolefin separator inserted between the anode and cathode. The cells were placed into a polymer-coated aluminum foil bag. 0.4mL of a 1.4 M solution of lithium bis(trifluoromethylsulfonyl)imide, in a 42:58 volume ratio mixture of 1,3-dioxolane and dimethoxyethane, was added as electrolyte and each electrochemical cell was vacuum sealed. Testing was performed at a discharge current of 0.42 mA/cm^2 to a voltage of 1.5V and charged at a current of 0.24 mA/cm^2 to 110% last half cycle capacity.

5. Performance of Cells Made from the Anodes of Examples A, B and C

The specific discharge capacity versus cycles of the cells fabricated from anodes of Example A, Example B, and Example C are summarized in Table1. These results show that the electrochemical cells utilizing the anodes with co-deposited lithium (Example B) outperformed

cells with untreated lithium anodes (Example A) and cells with lithium anodes post-treated with CO₂ (Example C):

TABLE 1			
SPECIFIC CAPACITY			
Cycle No.	Li Anode (A)	Li Co-deposit in situ (B)	Li with post plasma CO₂ (C)
10	485 mAh/g	528 mAh/g	470 mAh/g
20	430 mAh/g	444 mAh/g	383 mAh/g
30	226 mAh/g	357 mAh/g	174 mAh/g
40	96 mAh/g	170 mAh/g	87 mAh/g

In Table 2 the ratios of the discharge capacity of electrochemical cells utilizing untreated lithium anodes (Example A) are compared with electrochemical cells utilizing co-deposited lithium anodes (Example B) and lithium anodes post-treated lithium anodes treated with CO₂ (Example C). These comparisons show that the anode of Example C (with post-treatment of CO₂) provides no improvement in performance over a lithium anode with no CO₂ treatment (Example A) whereas the co-deposition of lithium and CO₂ (Example B) enhances performance of the electro-chemical cell:

TABLE 2		
RATIO OF CAPACITY TO LI ANODE (A)		
Cycle No.	Co-Deposited (B)	Post Treatment (C)
10	1.09	0.97
20	1.03	0.89
30	1.57	0.77
40	1.77	0.91

In summary, the present invention yields superior and unexpected results and is nonobvious over the cited art.

Finally, Applicant submits that the Examiner is incorrect in the assertion on pages 11-12 of the Office Action that applying elemental carbon to a lithium anode increases the conductivity of the anode. The conductivity of carbon is several orders of magnitude less than that of lithium.

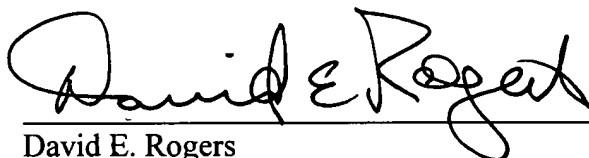
See Handbook of Chemistry & Physics, 60th Ed. P. F171 (the electrical resistivity of carbon at 0°C is 1375 micro ohms and the electrical resistivity of lithium at 0°C is 8.55 micro ohms).

Conclusion.

In view of the above amendments and arguments, reconsideration and allowance of this application are now believed to be in order, and such actions are hereby solicited. If any points remain in issue which the Examiner feels may be best resolved through a personal or telephone interview, the Examiner is kindly requested to contact the undersigned at the telephone number listed below.

Applicant hereby petitions for any extension of time which may be required to maintain the pendency of this case, and any required fee, except for the Issue Fee, for such extension is to be charged to **Deposit Account No. 19-3878**. Applicant further reserves the right to prosecute broader claims in this application or a continuation application

Respectfully submitted,



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